# Psychological trauma associated with the World Trade Center attacks and its effect on pregnancy outcome

Stephanie Mulherin Engel[a], Gertrud S. Berkowitz[a], Mary S. Wolff[a] and Rachel Yehuda[b,c]

[a]Department of Community and Preventive Medicine, [b]Traumatic Stress Studies Program, Department of Psychiatry, Mount Sinai School of Medicine, and [c]Bronx Veterans Affairs Medical Center, New York, USA

## Summary

*Correspondence:*
Dr Stephanie Engel,
Department of Community
and Preventive Medicine,
Mount Sinai School of
Medicine. One Gustave L.
Levy Place, Box 1043, New
York, NY 10029, USA.
E-mail:
Stephanie.Engel@mssm.edu

The destruction of the World Trade Center (WTC) on 11 September 2001 was a source of enormous psychological trauma that may have consequences for the health of pregnant women and their fetuses. In this report, we describe the impact of extreme trauma on the birth outcomes of women highly exposed to the WTC. We enrolled 187 women who were pregnant and living or working within close proximity to the WTC on 11 September. Among women with singleton pregnancies, 52 completed at least one psychological assessment prior to delivery. In adjusted multivariable models, both post-traumatic stress symptomatology (PTSS) and moderate depression were associated with longer gestational durations, although only PTSS was associated with decrements in infant head circumference at birth ($\beta = -0.07$, SE = 0.03, $P = 0.01$). The impact of stress resulting from extreme trauma may be different from that which results from ordinary life experiences, particularly with respect to cortisol production. As prenatal PTSS was associated with decrements in head circumference, this may influence subsequent neurocognitive development. Long-term follow-up of infants exposed to extreme trauma *in utero* is needed to evaluate the persistence of these effects.

## Introduction

The destruction of the World Trade Center (WTC) at approximately 9 am on 11 September 2001 was a source of enormous psychological trauma,[1–21] and consequently resulted in a unique opportunity to examine the effects of extreme trauma on the health of pregnant women. It has been suggested that psychological stress experienced during the course of pregnancy could affect pregnancy outcome, possibly through disruption of the hypothalamic-pituitary-adrenal (HPA) axis.[22–24] Although the impact of psychological trauma on the health of pregnant women and their fetuses is of public health concern, few circumstances allow its systematic evaluation because traumatic events may not be of uniform duration and intensity, and may not be attributable to a single point in time. In many circumstances, natural or man-made disasters involve stressful events that share many of these characteristics. However, the existing literature on the impact of disasters on pregnancy outcome is quite limited. Stress related to the experience of an earthquake has been associated with shorter gestational length,[25] an increase in the frequency of low birthweight neonates,[26] and a decline in the sex ratio at birth.[27]

Psychological trauma was a widespread and prevalent outcome of the terrorist attacks on the WTC. In a national probability sample telephone survey 3–5 days after 11 September, 44% of respondents reported one or more substantial symptoms of stress, and 35% of children had one or more stress symptoms.[18] In Manhattan, the effects were more pronounced. Between 16 October and 15 November, 7.5% of adults south of 110th Street endorsed symptoms consistent with a diagnosis of post-traumatic stress disorder (PTSD) related to the attacks, and 9.7% reported symptoms consistent with depression. Moreover, among respondents who lived south of Canal Street, closer to the WTC, the prevalence of probable PTSD was 20%.[7]

Compared with Washington DC (2.7%) and other metropolitan areas (3.6%), New York City residents experienced a higher burden of probable PTSD in the 1–2 months following 11 September (11.2%).[17] Predictors of PTSD were residence close to the WTC site, low social support, prior life stressors, panic attack at the time of the event or soon after, losing possessions in the attacks, and being involved in the rescue efforts.[8] Women were more likely to report symptoms related to PTSD than men,[5,8,16,17,19] and only a small proportion of those with severe responses were seeking treatment.[5] Among those exposed to the WTC disaster were an unknown number of pregnant women who may have lived or worked in close proximity to the WTC.

We established a prospective epidemiological study of 187 women, who were pregnant on 11 September or shortly thereafter, and at or near the WTC on or about 11 September . In this report we describe the relationship between prenatal psychological trauma and pregnancy outcome in a cohort of highly exposed women who completed psychological screening instruments prior to delivery.

## Methods

A total of 187 women were recruited who were within one of five zones of exposure at 9 am on 11 September 2001, or within the succeeding 3 weeks. Of these women, 3 miscarried and 2 were lost to follow-up with unknown birth outcomes. Enrolment began in February 2002 and continued until January 2003. Details of this cohort have been published.[28,29] Among women with singleton pregnancies ($n = 175$), 54 (43%) were interviewed prior to delivery and 52 (96%) of these women completed at least one prenatal psychological assessment (Table 1). We abstracted medical records for birth outcome information, including birthweight,

**Table 1.** Characteristics of women enrolled and interviewed prior to delivery ($n = 52$). World Trade Center pregnancy cohort, Mount Sinai School of Medicine 2002

| Covariates | n | % |
|---|---|---|
| Maternal age ≥35 years | 26 | 50.0 |
| Married | 51 | 98.1 |
| Caucasian | 38 | 73.1 |
| College degree or greater | 44 | 84.6 |
| Primiparae | 33 | 63.5 |
| Exposure zone on 11 September at 9 am | | |
|   Zone 1 | 19 | 36.5 |
|   Zone 2 | 17 | 32.7 |
|   Zones 3,4,5 | 10 | 19.2 |
|   Out of area[a] | 6 | 11.5 |
| Trimester on 11 September | | |
|   Before conception | 5 | 9.6 |
|   1st trimester | 35 | 67.3 |
|   2nd trimester | 12 | 23.1 |
|   3rd trimester | 0 | 0 |

| | Mean | SD |
|---|---|---|
| Pre-pregnancy body mass index (kg/m$^2$) | 23.7 | 5.1 |
| Gestational age at delivery (completed weeks) | 39.6 | 1.3 |
| Birthweight (g) | 3391.9 | 539.8 |
| Head circumference at birth (cm) | 34.4 | 2.0 |
| Birth length (cm) | 50.8 | 3.8 |
| Time between interview and 11 September (weeks) | 26.2 | 3.6 |
| Time between interview and delivery (weeks) | 4.1 | 3.8 |
| Post-traumatic Stress Checklist score | 29.2 | 10.4 |
| Beck Depression Index score | 7.9 | 5.5 |

[a]Out of the area at 9 am on 11 September, but in one of the zones of exposure in the following 3 weeks.

birth length, head circumference, and date and time of delivery. Gestational age at delivery was assigned using the maternal report of last menstrual period (LMP) date.

Eligibility criteria were pregnancy on 11 September or shortly thereafter and presence in one of five exposure zones at or near the WTC at 9 am on that day or within the next 3 weeks. The five exposure zones were assigned based on increasing distance from the WTC site, and inversely correlate with particulate matter (PM) air concentrations.[29] They were: (1) South of Murray Street; (2) South of Chambers Street and North of Murray Street; (3) South of Canal Street and North of Chambers Street; (4) Brooklyn Heights; and (5) the easternmost part of New Jersey across the Hudson River from the WTC. Zones 1 and 2 are within 8 blocks of the WTC.

At their enrolment visit in our research laboratory at the Mount Sinai School of Medicine, women were administered a baseline questionnaire that included socio-demographic information, gynaecological, reproductive and medical history, occupational history, physical activity during pregnancy, residential history, cigarette, alcohol, drug and caffeine use, and zone location on 11 September and the first 4 weeks after the attacks. Participants also completed self-administered psychological instruments at this visit. These included the Post-traumatic Stress Disorder Checklist (PCL),[30] Life Events Inventory (LEI),[31] State-Trait Anxiety Inventory (STAI),[32] and Beck Inventory of Depression (BDI).[33]

Both continuous and categorical versions of psychological exposure variables were considered in analyses. Categorical cut-points were chosen based on standard clinical criteria when possible, or percentiles if no standard clinical criteria exist. A dichotomous indicator variable for probable PTSD based on clusters of symptoms reported on the PCL was constructed using the standard clinical criteria of $\geq 1$ at least moderately distressing symptom of intrusive thoughts (PCL items 1–5), $\geq 3$ at least moderately distressing symptoms of avoidance or numbing (PCL items 6–12), and $\geq 2$ at least moderately distressing symptoms of hyperarousal (PCL items 13–17).[34] We will hereafter refer to the continuous version of the total PCL score as 'post-traumatic stress symptomatology (PTSS)', and the categorical version of the PCL symptom clusters as 'probable PTSD'. A categorical variable indicating the severity of depression was constructed using the standard BDI cut-points: normal (0–9) ($n = 33$); mild depression (10–18) ($n = 17$); moderate depression (19–29) ($n = 2$); severe depression ($\geq 30$) ($n = 0$).[35] Categories

**Table 2.** Correlation among symptoms of stress, depression, and anxiety among women who completed their interview prior to delivery in the World Trade Center pregnancy cohort, 2002

| | | | STAI | | LEI | | BDI |
|---|---|---|---|---|---|---|---|
| | | | State anxiety total score | Trait anxiety total score | Total negative life events | Total positive life events | Depression total score |
| PCL | PTSS | r | 0.71 | 0.37 | 0.64 | 0.09 | 0.77 |
| | | P | <0.01 | <0.01 | <0.01 | 0.53 | <0.01 |
| | | (n) | (50) | (50) | (50) | (50) | (50) |
| STAI | State anxiety | r | | 0.67 | 0.39 | 0.11 | 0.51 |
| | total score | P | | <0.01 | <0.01 | 0.46 | <0.01 |
| | | (n) | | (52) | (52) | (52) | (52) |
| | Trait anxiety | r | | | 0.23 | 0.07 | 0.17 |
| | total score | P | | | 0.10 | 0.64 | 0.24 |
| | | (n) | | | (52) | (52) | (52) |
| LEI | Total negative | r | | | | −0.01 | 0.72 |
| | life events | P | | | | 0.96 | <0.01 |
| | | (n) | | | | (52) | (52) |
| | Total | r | | | | | 0.12 |
| | positive | P | | | | | 0.41 |
| | life events | (n) | | | | | (52) |

STAI, State-Trait Anxiety Inventory; LEI, Life Events Inventory; BDI, Beck Inventory of Depression; PCL, Post-traumatic Stress Disorder Checklist.

of the STAI and LEI were created comparing subjects having total scores greater than the 75th percentile with those at or below the 75th percentile. We were underpowered to examine the effects of individual life events, such as death of a family member, on pregnancy outcome.

Across psychological instruments, symptom reporting tended to be highly correlated (Table 2). In particular, PTSS (based on the PCL) was highly correlated with state and trait anxiety (based on the STAI), negative life events (based on the LEI), and depression (based on the BDI). Because of these correlations, psychological domains were evaluated in separate statistical models to avoid problems of collinearity; however, state and trait anxiety, and positive and negative life events, were analysed together as they are elements of the same instruments. Covariates that were considered possible confounders of the relationship between psychological trauma and pregnancy outcome were maternal race (White vs. non-White and Hispanic); exposure zone on 11 September at 9 am (zone 1 vs. 3, 4, 5, and out of area; zone 2 vs. 3, 4, 5, and out of area); trimester on 11 September (preconception and first trimester combined vs. second trimester); maternal age (≥35 vs. younger); maternal education (college degree vs. less than college degree); pre-pregnancy body mass index (BMI) ($kg/m^2$) (continuous); and parity (primiparae vs. multiparae). All birthweight and head circumference models were adjusted for length of gestation.

Multivariable linear regression was implemented using PROC GLM in SAS vs. 8.02. Confounding was assessed in bivariate analyses using either chi-square or $t$-tests of association. A confounder was defined as a covariate that was associated with the main psychological exposure at a $P < 0.10$ level and that changed the main effect by 10%. Covariates not associated with the main exposures in bivariate analyses were not evaluated in regression models owing to our limited sample size. Model fit was examined by inspecting residuals. Observations with residual values that were >2 standard deviations from the mean were eliminated and the models were re-run (hereafter called 'reduced model'). Parameter estimates were compared between the original model and the reduced model. If the parameter estimates of the reduced model were within 10% of the original model, the final model included these observations.

## Results

The majority of the women enrolled while still pregnant ($n = 52$) were married (98.1%), primiparae (63.5%), and in zones 1 or 2 at 9 am on 11 September (69.2%). They were also predominantly Caucasian (73.1%), highly educated (84.6%), and in their first trimester on 11 September (67.3%). Women were interviewed on average 26.2 weeks after September 11, and an average of 1 month prior to delivery (Table 1). Three women had a preterm delivery (<37 completed weeks), and two women delivered low birthweight infants (<2500 g).

Post-traumatic stress symptomatology was marginally associated with maternal age, in that women aged 35 years and older had a slightly higher mean PCL score (i.e. they endorsed more symptoms of post-trau-

**Table 3.** Adjusted regression estimates for gestational age at delivery, birthweight, and birth head circumference by post-traumatic stress symptomatology (PTSS) or probable post-traumatic stress disorder (PTSD) in the World Trade Center pregnancy cohort, 2002

| | PTSS (range 17–69) ($n = 50$)[a], b (SD) | P-value | No PTSD[b] ($n = 47$)[a] adjusted mean | Probable PTSD[b] ($n = 4$)[a] adjusted mean | P-value |
|---|---|---|---|---|---|
| Gestational age at delivery (completed weeks) | 0.04 (0.02) | 0.03 | 39.6[c] | 40.6[c] | 0.17 |
| Birthweight (g) | −2.62 (6.43) | 0.69 | 3387.4[d] | 3469.9[d] | 0.73 |
| Birth head circumference (cm) | −0.07 (0.03) | 0.01 | 34.4[d] | 34.1[d] | 0.71 |

[a]Two subjects did not complete an entire PCL questionnaire. One of these subjects answered 16 of 17 items that allowed us to assign a 'probable PTSD' diagnosis based on reported symptoms; however, we were unable to compute a summary 'PTSS' score for either subject without complete data.
[b]Probable PTSD classified using the cluster diagnosis method: ≥ 1 at least moderately distressing symptom of *Intrusive Thoughts*, ≥ 3 at least moderately distressing symptoms of *Avoidance or Numbing*, and ≥ 2 at least moderately distressing symptoms of *Hyperarousal*.
[c]Mean adjusted for maternal age ≥ 35.
[d]Mean adjusted for maternal age ≥ 35 and gestational age at delivery.

**Table 4.** Adjusted regression estimates for gestational age at delivery, birthweight, and birth head circumference by depression symptoms in the World Trade Center pregnancy cohort, 2002

| | Depression symptoms (range 0–28) (n = 52), (SD) | P-value | Normal (no) depression[a] (n = 33) Adjusted mean | Mild depression[a] (n = 17) Adjusted mean | P-value[b] | Moderate depression[a] (n = 2) Adjusted mean | P-value[b] |
|---|---|---|---|---|---|---|---|
| Gestational age at delivery (completed weeks) | 0.04 (0.04) | 0.23 | 39.5[c] | 40.4[c] | 0.70 | 41.5[c] | 0.05 |
| Birthweight (g) | 10.01 (11.59) | 0.39 | 3419.1[d] | 3338.4[d] | 0.43 | 3156.1[d] | 0.43 |
| Birth head circumference (cm) | −0.05 (0.05) | 0.31 | 34.5[d] | 33.3[d] | 0.66 | 32.3[d] | 0.11 |

[a]Severity of depression cut-points derived using standardised criteria: normal (0–9); mild (10–18); moderate (19–29); severe (≥30).
[b]Reference category is normal (no) depression.
[c]Mean adjusted for maternal age ≥ 35.
[d]Mean adjusted for maternal age ≥ 35 and gestational age at delivery.

matic stress) (32.1 vs. 26.6, $P = 0.07$). Adjusted for maternal age, PTSS was positively associated with gestational duration, such that a 1-unit increase in PCL score increased gestational duration by 0.04 weeks ($P = 0.03$). Further, PTSS was inversely associated with infant head circumference at birth, such that a 1-unit increase in PCL score was associated with a 0.07 cm decrement in head circumference ($P = 0.01$), adjusted for maternal age and gestational age at delivery (Table 3). In the subset of women included in this analysis, few met the standardised criteria for probable PTSD ($n = 4$). We did not detect a relationship between probable PTSD and gestational duration, birthweight, or head circumference (Table 3).

Depressive symptomatology (BDI score) was also marginally associated with maternal age, in that older women endorsed slightly more depressive symptoms ($P = 0.10$). There was no association between increasing number of symptoms for depression and gestational duration, birthweight, or head circumference. Few women met the standardised criteria for moderate depression based on the BDI ($n = 2$), and none did for severe depression. Moderate depression was marginally associated with an increased duration of gestation, adjusted for maternal age ($P = 0.05$) (Table 4). However, there was no significant association between categories of depression and birthweight or head circumference.

Presence in zone 1 at 9 am on 11 September was associated with having a state anxiety above the 75th percentile at interview. However, there was no relationship between state or trait anxiety, and gestational age at delivery, birthweight, or birth head circumfer-

ence, adjusted for zone of exposure. Likewise, no covariates were significantly associated with having positive or negative life events above the 75th percentile, and there was no association between positive or negative life events and gestational age at delivery, birthweight, or head circumference.

## Discussion

The destruction of the World Trade Center (WTC) on 11 September 2001 created the largest acute environmental disaster that has ever befallen New York City.[36,37] It was also a source of enormous psychological trauma.[1–21] Exposure to the WTC disaster has been associated with increased risk of small-for-gestational age births in our cohort,[28] as well as decrements in birthweight, birth length, gestational duration, and head circumference in a contemporaneous cohort of pregnant women with term births exposed to the WTC.[38]

We restricted our analysis to those women who were interviewed before delivery. Although this resulted in a substantially reduced sample size, residual confounding owing to post-partum depression or changes in lifestyle factors related to the birth of an infant makes prenatal and postnatal psychological assessments not comparable. The entire study population ($n = 187$) was evenly distributed across trimesters on 11 September; however, because we restricted our analysis to only those women who enrolled and were interviewed prior to delivery and our study did not begin recruitment until February 2002, the majority of our analysis population was comprised of women who

were in their first trimester on 11 September. Therefore, we were underpowered to evaluate the interaction between trimester, traumatic stress, and pregnancy outcome.

We report in this paper a significant association between PTSS and longer gestational duration; a similar relationship was observed for moderate depression. Given the substantial overlap between symptoms of depression and traumatic stress, these findings were expected to be highly correlated. Although the literature is somewhat mixed,[39,40] it is commonly believed that prenatal stress increases risk of preterm delivery through alterations in the HPA axis;[22–24] specifically, stress may increase the production of cortisol and corticotrophin-releasing hormone which promote the biological cascade leading to delivery.[23] However, not all types of stress have the same effect on cortisol production. PTSD in particular is associated with depressed cortisol production in some studies,[41] whereas other types of stress and major depression tend to be associated with increased cortisol production.[41] These observations suggest that our findings are in agreement with the HPA hypothesis of preterm birth. For both probable PTSD and moderate depression, the mean gestational duration was within the normal range (37–42 completed weeks), which is unlikely to result in clinically significant adverse health effects. In addition, the small sample size warrants caution in interpretation.

We also found an inverse relationship between PTSS and infant head circumference at birth. Head circumference and depression were not significantly associated, which, in combination with the absence of any association between either life events or state and trait anxiety, suggests specificity in the relationship between head circumference and traumatic stress. Consequently, the aetiological impact of stress resulting from daily hassles or ordinary life experiences may be substantially different from that which results from natural or man-made disasters.

The relationship between PTSS in the prenatal period and decrements in head circumference may have clinical significance. Head circumference at birth correlates directly with brain weight;[42] and, both brain size and head circumference are predictive of IQ and cognitive ability.[43–45] Previous studies have found relationships between head circumference and maternal stress,[46,47] although only our study and Lou *et al.*[46] measured stress prior to delivery, and our study alone captures the effect of extreme trauma. It is unclear whether modest reductions in head circumference associated with traumatic stress exposure *in utero* will have any impact on subsequent cognitive development. The only prospective investigation of the effects of maternal prenatal stress resulting from a natural disaster (an ice storm in Canada) on childhood neuro-development followed 58 children to age 2.[48] There, prenatal stress explained a significant proportion of the variance in the Bayley Mental Development Index, as well as in productive and receptive language abilities, and the effects were stronger for women who were in their first trimester when the ice storm occurred.

Because we collected detailed assessments across multiple psychological domains prior to delivery, this study was uniquely able to directly evaluate the degree to which psychological trauma resulting from the WTC disaster affected pregnancy outcome in a subset of women enrolled in a longitudinal pregnancy cohort. Moreover, the uniform and discrete nature of the traumatic event allowed us to evaluate the impact of a stressor that was common to all participants and that occurred at a known time during pregnancy. We detected no significant confounding in the pregnancy outcome analysis by exposure zone with any psychological symptom except state-trait anxiety, but the possibility exists that psychopathology and unmeasured environmental exposures were highly correlated both with each other and with pregnancy outcome. However, we believe that zone is a good surrogate for the environmental exposures experienced on 11 September.

In a recent report, reconstructed particulate exposures among the women in our study based on zone of exposure were directly related to PM concentrations in air in late September and early October, with highest levels in zone 1.[29] On 11 September and immediately thereafter, PM levels in zone 1 were estimated to be above $100 \, \mu g/m^3$. Therefore, in our confounding assessments, we incorporated zone (location at 9 am on 11 September) to estimate exposures on 11 September. We are currently evaluating the long-term effects of prenatal stress on the neuro-developmental outcomes of the WTC children, which may further elucidate the relationship between PTSS, birth outcome and child development.

## Acknowledgements

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